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ORIGINAL PAPER

Attentional Learning Helps Language Acquisition Take Shape for Atypically Developing Children, Not Just Children with Autism Spectrum Disorders

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Abstract The shape bias—generalising labels to same shaped objects—has been linked to attentional learning or referential intent. We explore these origins in children with typical development (TD), autism spectrum disorders (ASD) and other developmental disorders (DD). In two conditions, a novel object was presented and either named or described. Children selected another from a shape, colour or texture match. TD children choose the shape match in both conditions, children with DD and 'high-verbal mental age' (VMA) children with ASD (language age > 4.6) did so in the name condition and 'low-VMA' children with ASD never showed the heuristic. Thus, the shape bias arises from attentional learning in atypically developing children and is delayed in ASD.

Keywords Autism spectrum disorders · Shape bias · Shape-as-cue · Attentional-learning-account · Word learning · Delay versus deviance

Introduction

Typically developing (TD) children rapidly generalise the names of objects from one exemplar to others within the same category (Bloom 2000). However, this is a complex process, as different instances of objects from the same class can have many dissimilar perceptual features. Yet TD children intuitively know that a big, shiny multi coloured beach ball, for example, has the same name as a small, rough, green tennis ball. They achieve this understanding by employing several lexical constraints and biases (Markman 1989), such as the 'shape bias' (Landau et al. 1988), or the assumption that same shaped objects have the same name. From as young as 2 years old, TD children generalise the word-object mapping 'ball' according to the circular shape of balls rather than other perceptual features such as size, texture (Landau et al. 1988) or colour (Baldwin 1989).

Although most children learn names for objects with relative ease, children with autism spectrum disorders (ASD) have potentially severe language acquisition difficulties (e.g. Boucher 2012; De Giacomo and Fombonne 1998; Eigsti et al. 2011) resulting from various factors, including impaired social pragmatic skills (Baron-Cohen et al. 1997; Preissler and Carey 2005; Walton and Ingersoll 2013) and lexical extension and categorisation difficulties (Gastgeb et al. 2006; Menyuk 1978; Naigles et al. 2013). Despite their socialisation impairments, children with ASD may be able to learn words using association and perceptual salience cues (e.g. Norbury et al. 2010; Preissler 2008). A shape bias deficit would help explain some of the specific difficulties that children with ASD have with language acquisition; rather than intuitively using object form to generalise verbal labels to different referents within the same object class, the name of each specific artefact might need to be learnt individually. This laborious process would make forming word-object mappings more difficult, time consuming and cognitively demanding than usual.

There are two competing theories regarding how TD children are able to show a shape bias, which revolve around whether the heuristic is controlled by social (shape-as-cue, or SAC, account) or associative (attentional-learning-account, or ALA) processes. The SAC account (e.g. Bloom 2000) proposes that object shape provides a good indicator as to the *referential intent* of the object's creator,

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who deliberately constructed the same kinds of objects to be of the same form. According to the SAC account, children become sensitive to the shape of objects before they have acquired much receptive vocabulary and this sensitivity extends to non-naming tasks, such as being asked whether similarly shaped objects are the '*same*' or '*like each other*'. Operation of the SAC account is guided by general intuitions about referential intent and therefore necessitates intact referential monitoring abilities. This account suggests that the shape bias helps children rapidly acquire words, particularly count nouns (Graham and Diesendruck 2010; Markson et al. 2008).

By contrast, the ALA (e.g. Smith et al. 1996) proposes that the shape bias arises due to children simply learning to *associate* same shaped objects with the same name. This association develops through frequent co-occurrences between objects with specific shapes having specific labels. Therefore, the shape bias is exclusive to naming without extending to non-lexical classification tasks (e.g. Landau et al. 1988; Smith et al. 1996; but see Samuelson and Smith 2005). According to the ALA, children have already acquired a considerable amount of language, particularly count nouns (50+), prior to showing the shape bias. Indeed, this early noun vocabulary facilitates shape bias understanding (Samuelson 2002; Smith et al. 2002; Tek et al. 2008).

TD children show the shape bias more when the object is named (e.g. Imai et al. 1994; Landau et al. 1988; Smith et al. 1996), which supports the ALA. However, there is also evidence that TD children possess a shape bias in some non-lexical situations (e.g. Diesendruck and Bloom 2003), which supports the SAC account. It has been suggested that the shape bias begins as a word learning strategy for TD children and then extends to other forms of object classification by adulthood (Landau et al. 1988). As children with ASD have difficulties inferring referential intent (D'Entremont and Yazbek 2007; Preissler and Carey 2005; Prizant and Wetherby 1987), the SAC account would hypothesise that they do not possess the shape bias. Conversely, as children with ASD are able to learn words via association (Parish-Morris et al. 2007; Preissler 2008), the ALA would hypothesise that they show a shape bias in naming activities.

However, abstracting commonality in shape involves both categorisation skills and the ability to attend to the global shape of objects, both of which are impaired in ASD, given evidence for difficulties with prototype formation (Klinger and Dawson 2001) and a preference for local rather than global processing (e.g. Frith 1989; Happé and Frith 2006). This latter behaviour is typically described as weak central coherence (but see Mottron et al. 2003), and would predict that children fixate on parts of objects rather than the object as a whole. This could contribute to a shape bias deficit, as well as difficulties with the whole object assumption (Markman 1989) and word-object mapping errors. For instance, focusing on the stem of an apple when the word 'apple' is overheard may cause children to map the word 'apple' only to the stem, instead of the global shape of the object. Due to these underlying differences in cognitive style, it is possible that children with ASD *never* acquire a shape bias. An alternative possibility is that children with ASD simply have a shape bias delay, showing the heuristic only after explicitly learning certain rules.

This argument is not new; many researchers have previously investigated delay or deviance accounts of word learning in ASD (e.g. Bartolucci et al. 1976; Eigsti and Bennetto 2009; Howlin 1984; Mitchell et al. 2006; Van Meter et al. 1997). A delay account would predict that children with ASD may eventually learn to use the shape bias heuristic, but not until they have more experience with objects (i.e. a higher chronological age, or CA) and/or superior receptive language (i.e. a higher verbal mental age, or VMA) than is usual. If the shape bias is deviant, however, children with ASD may *never* use the familiar form of an object to facilitate their word learning. To investigate these hypotheses, it is necessary to include a group of children with wide variability in language skills, specifically to test whether the shape bias emerges at a later point in development.

Only two studies to date (Hartley and Allen 2014; Tek et al. 2008) have investigated the use of the shape bias in children with ASD. Tek et al. (2008) compared the performance of 14 children with ASD and 15 TD children during four different developmental time points over a year-long period. At the initial session, the TD children had a mean CA of 20.5 months and the children with ASD had a mean CA of 33.2 months. Both implicit (Intermodal Preferential Looking, or IPL) and explicit (pointing) measures were used to track performance in a name and no name condition. In 'name' trials, a novel object was named (e.g. *'this is a zup'*), and children were asked to look at or point to the '*zup*' from one similarly shaped and one similarly coloured object in the test trials. The 'no name' trials followed a similar procedure but children were just told *'look at this'* and were then required to either look at or point to *'the same'* during the test trials.

In the IPL trials, the TD group looked longer at the shape match in name trials (but equally long at both objects in no name trials) from 24 months old, although the children with ASD showed no preference for the shape match across all four sessions in either condition. The pointing trials showed a different pattern of results; here, both groups selected the shape match more often than the colour match, but in both conditions. The authors concluded that the shape bias was not present in the children with ASD, due to their failure in the IPL trials and lack of discernible difference between the name and no name conditions in the pointing task. One perplexing possibility is that both the ASD and TD groups seem to be operating via the SAC account in the pointing trials, as they showed a general preference for shape across lexical and non-lexical situations. This possibility needs further investigation and replication with a larger sample.

Additional evidence for a difference in using shape as a cue for lexical extension in ASD was recently provided by Hartley and Allen (2014), in a study about pictorial reference. Children with ASD with a verbal mental age (VMA) of 3 were able to extend labels learnt for images to novel pictures and objects of the same shape *and* colour. However, they also extended labels to stimuli that shared the same shape *or* colour. Thus, Hartley and Allen (2014) proposed that the children with ASD showed a 'fundamental misunderstanding of the rules that govern symbolic word-picture-object relations' (p. 2069), and suggest that they were unable to correctly use shape to constrain lexical generalisation.

The current study extends the research of Tek et al. (2008) and Hartley and Allen (2014). First, we include older children than those previously recruited, considering that Tek et al. (2008) left open the possibility that the children in their study may simply have been too young to consistently use the shape bias for word learning. As the shape bias is considered to be completely developed in TD children by 2-years-old (Jones 2003; Landau et al. 1988; Tek et al. 2008) children with a VMA above 2 participate in the present experiment. To investigate the delay versus deviance hypothesis, each group is split into a 'high-VMA' and 'low-VMA' category based on the median VMA of the sample.

A second aim of our study is to investigate the shape bias not only in children with ASD, but in children with developmental disorders (DD) excluding ASD, because word learning difficulties have also been documented in this population (e.g. Franken et al. 2010; Rice et al. 2005). Interestingly, 'late talkers', or children who are delayed in learning how to speak, fail to show the shape bias, sometimes forming word-object mappings according to texture (Jones 2003). Thus, it is important to establish whether children with other developmental difficulties also have a shape bias deficit, and this can furthermore reveal whether any deficits or differences are autism-specific, or are instead a result of cognitive delay.

Finally, we aim to test whether the shape bias can be explained by the SAC account or ALA across our three populations (TD, ASD and DD). We base our study on the pointing task of Tek et al. (2008), as it is more age appropriate for our sample, and because the results obtained in that condition require further investigation and leave open the possibility that the SAC account drives the shape bias in explicit tasks. To avoid potential bias between conditions, we adopt a between subjects design. Across four trials, a novel object was presented and either named (e.g. *'this is a dax!'*) or described (*'this is nice'*). As 'late talkers' sometimes generalise words to objects of the same texture (Jones 2003), we add a texture match to the test array, which also consists of a shape match and a colour match. Children are simply asked to give the experimenter the other *'dax'* (name condition) or the other *'one'* (no name condition).

If the shape bias is controlled by the SAC account, TD children and children with DD are predicted to select the shape match in both the name and no name condition, but children with ASD are not predicted to select the shape match in either condition. However, given Tek et al.'s (2008) results in the pointing task, an alternative possibility is that the ASD group select the shape match in both conditions. If the shape bias is explained by the ALA, all groups of children are expected to select the shape match in the name condition but not the no name condition. However, due to the difficulties children with ASD experience with categorisation and global processing they might not select the shape match in either condition. If the shape bias is delayed in ASD, high VMA children with ASD are hypothesised to show the shape bias, although low VMA children with ASD are not. If the shape bias is deviant in ASD, both high and low VMA children with ASD are hypothesised to have a shape bias deficit.

Overall, this study adds to the growing literature investigating categorisation impairment (Gastgeb et al. 2006; Gastgeb et al. 2011; Klinger and Dawson 2001) and lexical biases (Hartley and Allen 2014; Preissler and Carey 2005; Tek et al. 2008) in ASD. It helps uncover whether the underlying mechanisms controlling the shape bias are social (SAC) or associative (ALA). Our results inform theories of word acquisition and provide evidence for the developmental trajectory of the emergence of the shape bias across atypical development, not just ASD.

Methods

Participants

Participants were recruited from mainstream schools and day nurseries (TD children) and specialist schools, parental support groups and word of mouth (children with ASD and children with DD) and tested in North West England. Ethical permission had been granted from Lancaster University to carry out the research. Informed consent was obtained from children's parents. Demographic details for participants are provided in Tables 1 and 2.

Table 1 Demographics for three groups of participants

	TD (N = 66, 33 name)	ASD (N = 62, 32 name)	DD (N = 44, 23 name)
Mean CA (SD)			
Name	4.25 (1.41)	9.90 (3.63)	8.88 (2.13)
Range	2.08–7.33	4.67–17.25	5.17–11.08
No name	4.54 (1.52)	9.57 (2.96)	9.29 (2.68)
Range	2.00–7.17	4.42–17.42	5.42–15.58
Mean VMA (SD)			
Name	5.06 (2.07)	5.23 (1.98)	4.60 (1.70)
No name	5.30 (2.37)	5.30 (2.04)	4.31 (1.50)
Mean Raven's (SD)			
	13.36 (7.34)	17.69 (8.12)	11.36 (7.17)
Mean CARS (SD)			
	16.22 (2.52)	33.72 (7.51)	23.70 (4.81)
Mean SCQ (SD)			
	3.21 (2.90)	17.45 (6.91)	8.30 (5.63)

Table 2 Demographics for six groups of participants

	TD-low VMA (N = 35, 17 name)	TD-high VMA (N = 31, 16 name)	ASD-low VMA (N = 28, 14 name)	ASD-high VMA (N = 34, 18 name)	DD-low VMA (N = 22, 11 name)	DD-high VMA (N = 22, 12 name)
Mean CA (SD)						
Name	3.35 (.70)	5.20 (1.36)	7.80 (2.97)	11.54 (3.28)	8.38 (2.41)	9.34 (1.85)
No name	3.54 (.54)	5.73 (1.45)	9.56 (3.61)	9.59 (2.36)	8.62 (1.71)	10.02 (3.41)
Mean VMA (SD)						
Name	3.49 (.52)	6.73 (1.76)	3.64 (.65)	6.46 (1.78)	3.15 (.40)	5.93 (1.26)
No name	3.58 (.45)	7.35 (2.07)	3.54 (.63)	6.84 (1.50)	3.13 (.57)	5.60 (1.04)
Mean Raven's (SD)						
	8.39 (3.18)	18.52 (6.88)	13.95 (7.09)	20.18 (7.88)	7.25 (3.17)	14.65 (7.82)
Mean CARS (SD)						
	15.80 (1.44)	17.27 (4.09)	36.16 (8.08)	31.65 (6.45)	24.73 (4.77)	22.80 (4.83)
Mean SCQ (SD)						
	3.00 (2.74)	3.78 (3.42)	18.87 (6.73)	16.19 (6.95)	8.50 (6.01)	8.12 (5.43)

A total of 172 children took part in the study (66 TD, 62 ASD, 44 DD). One hundred and thirteen participants were male (35 TD, 52 ASD, 26 DD) and 59 were female (31 TD, 10 ASD, 18 DD). There were 88 children in the name condition and 84 in the no name condition. All children with ASD received a clinical diagnosis of autism by a qualified educational or clinical psychologist, using standardised instruments (i.e. Autism Diagnostic Observation Scale and Autism Diagnostic Interview—Revised: Lord et al. 2002; Lord et al. 1994) and expert clinical judgment.[1] The children with DD had various conditions, including intellectual disability, Down Syndrome and rarer chromosomal disorders. Participants were grouped according to their diagnostic category (Table 1). In order to investigate the delay versus deviance hypothesis, they were then further subcategorised within their diagnostic category according to the median VMA of the sample (Table 2), totalling six groups: TD-low VMA, TD-high VMA, ASD-low VMA, ASD-high VMA, DD-low VMA and DD-high VMA.

Cognitive Tests

Children's VMA was determined by administering the British Picture Vocabulary Scale—Second Edition (BPVS-

[1] With two exceptions, all of the DD children had also received a formal diagnosis of their disorder. The data was not excluded from the study from the two DD-low VMA children who had not been officially diagnosed with any DD because, in addition to attending a specialist school, their VMA (3.67 and 3.75 respectively) was considerably younger than their CA (10.75 and 10.83 respectively). The possibility that these children had undiagnosed ASD was ruled

Footnote 1 continued
out by both children scoring below the clinical threshold for ASD on both the CARS and SCQ questionnaires.

II; Dunn et al. 1997).[2] Their nonverbal reasoning was assessed by administering Raven's Coloured Progressive Matrices (Raven's; 2003), which has a minimum raw score of 0 and a maximum of 36. The three groups had equivalent VMA's (all $p > .05$). The TD-high VMA children had an older VMA than the DD-high VMA children ($p = .005$), although ASD-high VMA and DD-high VMA were VMA matched, as were ASD-high VMA and TD-high VMA (both $p > .05$). There were no within group differences in VMA between participants in the name and the no name condition (all $p > .05$).

CARS and SCQ Scales

The Childhood Autism Rating Scale (CARS; Schopler et al. 1988) and the lifetime version of the Social Communication Questionnaire (SCQ; Rutter et al. 2003) were completed for the majority of children (CARS: 39 TD, 48 ASD, 29 DD. SCQ: 34 TD, 51 ASD, 32 DD) by their parent or teacher to confirm or rule out ASD. Scores on the CARS range from 15 to 60, with scores of 30 or above in the ASD range. Scores on the SCQ range from 0 to 39, with scores of 15 or above in the ASD range. The vast majority of children scored according to their diagnosis on at least one of the questionnaires, with only 9 children (7 ASD, 2 DD) not scoring according to their diagnosis on either questionnaire. As removing these children from the analyses led to almost identical results, and considering that they had all been officially diagnosed with their developmental disorder, they were not excluded from the sample.

Materials

A total of sixteen objects were presented to the children across four trials (see Fig. 1).[3]

At the beginning of each trial, children were shown a novel object, which was either named (name condition) or described as being '*nice*' (no name condition). Participants were then presented with three test objects per trial: one shape match, one colour match and one texture match.

Fig. 1 Example object set. The novel object is a sink stopper covered in *orange tissue paper*, the shape match test object is a sink stopper covered in *blue cotton*, the colour match test object is an *orange lemon squeezer* and the texture match test object is a bowl scraper covered with *pink tissue paper* (Color figure online)

Procedure

Participants completed the experimental and background measures in a quiet area of their school, day nursery, parental support group or Lancaster University University. Task order was counterbalanced. In some cases, the child's parent or a member of staff at their school or nursery was also present in the room. Adults in attendance were instructed to simply watch the study and avoid intervening in any way.

The experimenter presented the novel object. In the name condition, she said *'see this one? This is a dax (parlu/wug/gazzer). It's a dax'*. In the no name condition, she said *'see this one? This is nice. It's nice.'* The experimenter then placed the novel object on the table. Following this, she showed the child the three test objects, which she laid on the table. These were placed directly in front of the child, with the original object still in view, behind the test objects. The positioning of the three test objects (left, centre or right), the order that the four object sets were shown and, for the name condition, the word uttered to refer to the novel object, were all counterbalanced.

In the name condition, the experimenter asked *'can you give me the other dax?'* In the no name condition, she asked *'can you give me the other one?'* Only intentional responses (purposefully giving or sliding an object towards the experimenter, clearly pointing towards an object or providing an unambiguous description of the object) were scored (see Preissler and Carey 2004). Six children (2 TD,

[2] Two ASD-low VMA children had a raw score on the BPVS below the basal start point of 2.33. However, as both children were very close to this start point, they were conservatively assigned VMA's of 2.25 and 2.00 based upon their raw score. For example, the child who was assigned a VMA of 2.25 had a raw score of 14 on the BPVS, where a raw score of 15 equates to a VMA of 2.33. As the shape bias is present by two-years-old in TD children, these participants were not excluded from the study.

[3] Fourteen out of the sixteen stimuli had been modified from kitchen or household equipment (e.g. covering a bowl scraper with pink tissue paper, see Fig. 1), therefore would not have been seen by any of the children before. The two remaining stimuli consisted of unusual kitchen equipment, which children were very unlikely to be familiar with (the lemon juicer included in Fig. 1 and a utensil hook). No child volunteered a name for any of the stimuli. Thus, we could be reasonably confident that the objects were novel to the children.

2 ASD, 2 DD) completed only three out of the four trials and two children (1 TD, 1 ASD) completed only two out of the four trials, due to non-compliance.

Favourite Object Control Trials

After an unrelated task (e.g. the BPVS or Raven's), the child was presented with the test objects again and asked to give the experimenter their favourite one. The objects were presented one set at a time in the same sequential order and position as they had appeared during the experimental phase. The experimenter asked the child *'can you give me your favourite one? Which is the one that you like the best?'* These trials took place in order to see if the test objects chosen for each set were of relatively equal saliency, thus chance performance was expected. If for some reason children *were* more attracted to some objects than others, the favourite object trials helped establish whether children were simply picking the object they were most attracted to during the test trials.

Results

SAC Versus ALA

If the SAC account is correct, the TD and DD children would be expected to select the shape match test object in both conditions but the children with ASD would not be expected to select the shape match more than the other two test objects in either condition. If the ALA is correct, all three groups of children are expected to select the shape match in the name condition but not in the no name condition. Alternatively, due to children with ASD having categorisation impairments and a preference for local processing, children with ASD may not select the shape match in either condition. Children's shape match choices were summed over trials from 0 (did not choose the shape match on any trial) to 1 (choose the shape match on every trial) and then converted into proportions. Proportions were used instead of frequencies, as a small minority of children did not complete all trials. Table 3 shows the proportion of times children selected the shape match test object in the name and no name condition.

One-sample t-tests were run for the three groups of children to establish if participants choose the shape match test object as the referent above a chance level of .33. All three groups of children selected the shape match in the name condition [TD, $t(32) = 7.14$, $p < .001$, $d = 1.23$: ASD, $t(31) = 5.84$, $p < .001$, $d = 1.03$: DD, $t(22) = 5.38$, $p < .001$, $d = 1.12$], although in the no name condition, only the TD children [$t(32) = 6.29$, $p < .001$, $d = 1.09$] selected the shape match.[4] A 3 (Group) × 2 (Condition) between subjects ANOVA compared the proportion of shape match choices for the three groups of children. There were significant main effects of Group [$F(2) = 6.20$, $p = .003$, $\eta p^2 = .07$] and Condition [$F(1) = 21.61$, $p < .001$, $\eta p^2 = .12$] and a significant interaction [$F(2) = 3.17$, $p = .044$, $\eta p^2 = .04$] (see Fig. 2).

Table 3 Mean proportion of shape match, colour match and texture match responses (SD) for three groups of participants

	TD	ASD	DD
Shape			
Name	.76 (.35)*	.70 (.36)*	.71 (.34)*
No name	.70 (.34)*	.41 (.26)	.35 (.37)
Colour			
Name	.14 (.23)	.20 (.29)	.14 (.20)
No name	.21 (.29)	.31 (.22)	.39 (.32)
Texture			
Name	.10 (.20)	.10 (.15)	.15 (.27)
No name	.09 (.21)	.28 (.25)	.26 (.23)

* $p < .05$ higher than chance (.33)

Post hoc tests (Tukey–Kramer) confirmed that the TD children choose the shape match more than both the ASD ($p = .014$) and DD ($p = .011$) participants. Examining the children's mean proportion of shape match responses for the name (TD = .76, ASD = .70, DD = .71) and no name (TD = .70, ASD = .41, DD = .35) condition suggests that the children with ASD and the children with DD selected the shape match more in the name than no name condition, supporting the ALA. However, the TD children selected the shape match equally in both the name and no name condition, supporting the SAC account. This was confirmed by performing three one-way ANOVAs [TD, $F(64) = .61$, $p = .439$: ASD, $F(60) = 13.48$, $p = .001$, $\eta p^2 = .18$: DD, $F(42) = 11.62$, $p = .001$, $\eta p^2 = .22$].

Relation Between Shape Bias Performance, CA, VMA and Raven's

For TD children in the no name condition and children with ASD in the name condition, selecting the shape match test object was positively correlated with both CA [TD, $r(33) = .35$, $p = .045$. ASD, $r(32) = .35$, $p = .049$) and

[4] If the more stringent Bonferroni correction is applied, using the alpha value of .008 for three groups (six comparisons) and .004 for six groups (twelve comparisons), the results for seventeen out of the eighteen comparisons remain significant, the only exception being the results for the DD-low VMA children. However, we did not do this following recent criticism against correcting for multiple *t* tests on the grounds that this procedure inflates the risk of type 11 errors (e.g. Nakagawa 2004; Rothman 1990) or is simply not necessary (Perneger 1998).

Table 4 Mean proportion of shape match, colour match and texture match responses (SD) for six groups of participants

	TD-low VMA	TD-high VMA	ASD-low VMA	ASD-high VMA	DD-low VMA	DD-high VMA
Shape						
Name	.69 (.38)*	.84 (.30)*	.48 (.39)	.88 (.23)*	.58 (.36)*	.83 (.29)*
No Name	.60 (.33)*	.82 (.31)*	.34 (.16)	.47 (.31)	.20 (.22)	.50 (.46)
Colour						
Name	.16 (.25)	.11 (.21)	.38 (.35)	.06 (.11)	.20 (.17)	.09 (.22)
No name	.32 (.33)	.08 (.15)	.34 (.23)	.28 (.22)	.50 (.30)	.27 (.32)
Texture						
Name	.15 (.20)	.05 (.19)	.14 (.16)	.06 (.14)	.22 (.32)	.08 (.22)
No name	.08 (.15)	.10 (.26)	.32 (.23)	.25 (.27)	.30 (.25)	.23 (.22)

* $p < .05$ higher than chance (.33)

VMA [TD, $r(33) = .43$, $p = .012$. ASD, $r(32) = .51$, $p = .003$]. Raven's score was also positively correlated with shape match responses for the TD children in the no name condition [$r(31) = .40$, $p = .026$]. Selecting the shape match was also positively correlated with VMA [$r(21) = .47$, $p = .031$] and Raven's [$r(17) = .56$, $p = .021$] for DD children in the no name condition. When partial correlations controlling for CA were performed, VMA and shape match responses remained significant for the ASD and DD groups [ASD, name: $r(29) = .42$, $p = .018$. DD, no name: $r(18) = .62$, $p = .003$] and Raven's remained significant for the DD children [$r(14) = .66$, $p = .005$].

A stepwise linear regression analysis entering CA, VMA and Raven's score as predictor variables was performed separately for the three groups [TD, Adj $R^2 = .07$, $F(1,53) = 5.16$, $p = .027$: ASD, Adj $R^2 = .08$, $F(1) = 5.61$, $p = .022$: DD, Adj $R^2 = .19$, $F(1) = 9.06$, $p = .005$]. Only VMA significantly predicted shape match responses for all groups [TD, $\beta = .298$, $p = .027$; ASD, $\beta = .309$, $p = .022$; DD, $\beta = .464$, $p = .005$]. Thus, the correlation and regression analyses provide converging evidence that VMA is related to shape match performance across groups.

Delay Versus Deviance

From the aforementioned results, it would appear that TD children select the shape match in both conditions, supporting the SAC account, but children with ASD *and* children with DD only select the shape match in the name condition, supporting the ALA. However, the overall median VMA of the sample is 4.6 (TD, median VMA = 4.29: ASD, median VMA = 4.91: DD, median VMA = 4.42), whereas TD children show the shape bias from as early as 2 years old (Landau et al. 1988). There is no way of establishing from the above data whether children with ASD show a shape bias in the name condition at the usual developmental time point or whether the shape bias is delayed in ASD. Hence, each group was split into 'low-VMA' (<4.6) and 'high-VMA' (>4.6) subcategories to test the delay versus deviance hypotheses (see Table 4).

One sample t-tests showed that both TD groups choose the shape match above chance levels (.33) in both conditions [TD-low VMA: name, $t(16) = 3.91$, $p < .001$, $d = .95$. No name, $t(17) = 3.40$, $p = .003$, $d = .80$. TD-high VMA: name, $t(15) = 6.69$, $p < .001$, $d = 1.67$. No name, $t(14) = 6.17$, $p < .001$, $d = 1.59$]. The ASD-high VMA children and both DD groups selected the shape match in the name condition [ASD-high VMA: $t(17) = 10.02$, $p < .001$, $d = 2.36$: DD-high VMA, $t(11) = 6.04$, $p < .001$, $d = 1.74$: DD-low VMA, $t(10) = 2.33$, $p = .042$, $d = .70$].[4] All other results were not significant.

A six (Group) × 2 (Condition) between subjects ANOVA for proportion of shape match choices confirmed an effect of Group [$F(5) = 7.63$, $p < .001$, $\eta p^2 = .19$] and Condition [$F(1) = 21.62$, $p < .001$, $\eta p^2 = .12$]. Post hoc tests showed that the ASD-low VMA and DD-low VMA participants choose the shape match less often than the TD-low VMA (both $p = .050$), TD-high VMA (both $p < .001$), ASD-high VMA (ASD-low VMA, $p = .012$: DD-low VMA, $p = .013$) and DD-high VMA (ASD-low VMA, $p = .036$: DD-low VMA, $p = .035$) participants. Overall, children selected the shape match more frequently in the name than no name condition (see Fig. 3).

Favourite Object Control Trials

The shape match test object was never chosen as the favourite object above chance levels for any of the groups (all $p > .05$), suggesting that children were not drawn to the shape match in the test trials due to salience or a simple preference.

Discussion

This study investigated whether TD children, children with ASD and DD children show a shape bias for word learning,

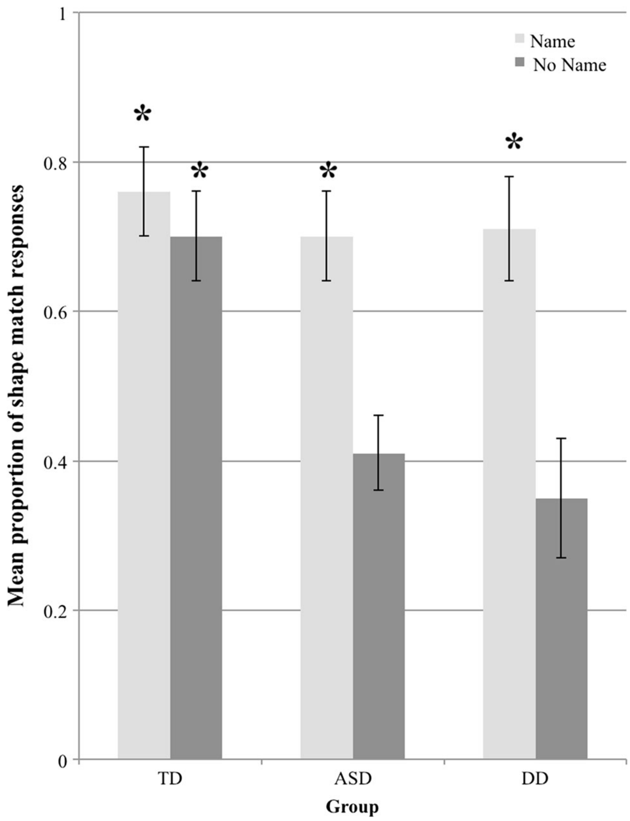

Fig. 2 Mean proportion of shape match responses per three groups and condition (with standard *error bars*)

in both a naming (*'it's a dax!'*) and non-naming (*'it's nice'*) context. We explored whether the SAC or ALA account underpins shape bias performance across all groups, which allowed us to probe for autism-specific differences. Additionally, splitting each group into younger and older subcategories helped establish whether the shape bias is present at the usual developmental time point for children with ASD, or is delayed. The results suggest that the shape bias is controlled by the ALA for children with ASD and DD but the SAC account for TD children. Furthermore, the shape bias is delayed in ASD. We discuss the results for the three groups individually, then relate children's overall performance to the findings of Tek et al. (2008).

With regards to typical development, participants of low and high VMA selected the shape match as the referent in both conditions, which is consistent with several earlier studies that show children categorise by shape in both lexical and non-lexical contexts (Diesendruck and Bloom 2003; Graham and Diesendruck 2010). Crucially, these results are also consistent with Tek et al.'s (2008) pointing task, in which TD children chose the shape match rather than colour match in both naming and non-naming conditions using an explicit measure. Conversely, others argue that the shape bias is specific to naming in young children (e.g. Imai et al. 1994; Landau et al. 1988; Smith et al. 1996). One possible reason for these conflicting findings may be due to variation in the way the test question is phrased. Children are more likely to choose the shape match in non-lexical situations if category membership (e.g. *'pick another object like this'*) rather than perceptual categorisation (e.g. *'pick the object that goes together with this'*) is highlighted, as the former emphasises that the objects are of the same kind and therefore should be classified together (Diesendruck and Bloom 2003).

It is also the case that the low VMA TD group in the no name condition of the present study were just over 3-and-a-half years old, whereas TD children first start to show a lexical shape bias from as early as 2-years-old (Landau et al. 1988). Previous research (Baldwin 1989; Landau et al. 1988) suggests that the shape bias strengthens during development. TD individuals may originally only show a shape bias in the name condition, at 2, prior to also showing it in the no name condition, by 3-and-a-half (Baldwin 1989, but see Diesendruck and Bloom 2003). The fact that proportion of shape bias responses was positively correlated with both CA and VMA for the TD children in the no name condition is a further indication that older TD children are more likely than younger TD children to show a non-lexical shape bias.

Unlike both groups of TD children, participants with ASD only displayed a shape bias when the object was named, indicating that the heuristic is controlled by a process of attentional learning and not referential intent for children with ASD. This is consistent with past research suggesting that children with ASD learn words from association (e.g. Baron-Cohen et al. 1997; Norbury et al. 2010; Preissler 2008; Preissler and Carey 2005) and have difficulty monitoring referential intent (D'Entremont and Yazbek 2007; Preissler and Carey 2005; Prizant and Wetherby 1987). The shape bias was also delayed for participants with ASD; when the groups were split by VMA only the high VMA children showed a shape bias, supporting previous research suggesting that individuals with ASD have delays in aspects of language acquisition (e.g. Bartolucci et al. 1976; Boucher 2012; Charman et al. 2003; Eigsti and Bennetto 2009; Eigsti et al. 2011).

One possibility for the shape bias delay in ASD is that it is due to weak central coherence (Frith 1989; Happé and Frith 2006); young children with ASD may focus more on individual parts of objects than on the object as a whole, leading them to mismap new labels to parts of objects, neglecting the overall object shape. As children with ASD can attend to global properties of objects when they are explicitly told to do so (Koldewyn et al. 2013; Plaisted et al. 1999), direct instruction may facilitate shape bias understanding in ASD. Future work should investigate this hypothesis.

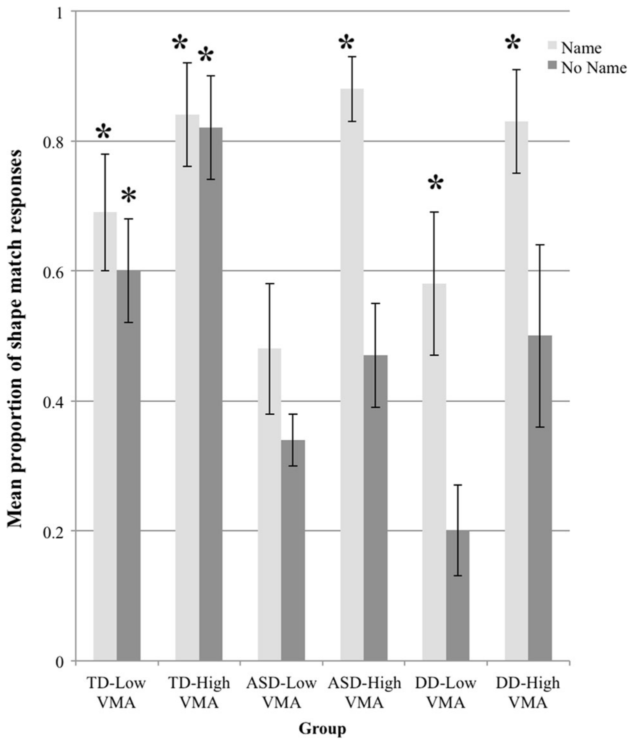

Fig. 3 Mean proportion of shape match responses per six groups and condition (with standard *error bars*)

A further possibility for the shape bias delay in ASD is that these children apply different processes to achieve success in cognitive tests (e.g. Eisenmajer and Prior 1991; Frith et al. 1991; Happé 1995; Yirmiya et al. 1992). For example, children with ASD may use explicit verbal mediation and logic to pass false belief tasks, therefore requiring an older VMA than TD children (Happé 1995). Furthermore, intelligence is positively correlated with performance in empathy and conservation tasks for children with ASD, but not for TD children (Yirmiya et al. 1992). Having a higher VMA, better cognitive skills and experience of intervention programmes such as Applied Behavioural Analysis (ABA; Lovaas 1987) may all help children with ASD explicitly 'hack out' solutions to problems. These children may rote learn certain rules in order to facilitate category formation, instead of extracting a common prototype (Klinger and Dawson 2001). This is in contrast to TD children's intuitive reasoning, which may be more automatic (Frith et al. 1991).

Although it is not surprising that children with ASD show a shape bias through attentional processes, rather than referential intent, the results for the DD children are somewhat unexpected. When the DD group is considered as a whole, the pattern of results is virtually identical to the ASD group, in that shape is used to constrain lexical, but not non-lexical generalisation. This is the traditional interpretation of what it means to have a 'shape bias' (i.e. it only surfaces in naming situations), and supports ALA based accounts. Of particular interest is that, although the proportion of shape based responses in the naming condition increases between the low VMA and high VMA group with DD, it is still present in the low VMA cohort. This suggests that the delay seen in the ASD group is autism-specific.

Nevertheless, the DD children's pattern of performance differs from what we found in our TD group, who also used shape for generalisation in the non-naming condition. One possibility is that the unique life experiences the atypically developing groups have, as a direct consequence of their developmental difficulties, contribute to their different route of language acquisition (Karmiloff and Karmiloff-Smith 2001; Karmiloff-Smith et al. 2012). It is also possible that children with DD have lower intention monitoring skills than the TD group, and thus do not use shape as a cue to discerning referential intent in pragmatic situations. However, as we did not independently measure intention monitoring abilities in the present study, this claim is simply speculative rather than evidence-based. Future work should include a separate measure of intention reading skills.

Although we have identified a differential pattern of performance across conditions and groups, we also found a core commonality in the use of the shape bias. Specifically, we obtained evidence that VMA is related to, and uniquely predicts, shape match performance, not just for children with ASD, but for all three groups of children. This suggests that it is not simply maturation or increased experience with objects that drives the use of the shape bias, but instead language comprehension (as measured here by the BPVS). This supports earlier studies that have found that the absence of a shape bias has been linked to possessing a limited vocabulary (e.g. Jones 2003; Smith et al. 2002), and identifies one common foundation for word acquisition across typical and atypical development.

Overall, the results of this study support Hartley and Allen (2014), who found that children with ASD who had a similar VMA to the younger ASD group in our study generalised object labels according to colour as well as shape. However, the results are in slight contrast to Tek et al. (2008), who found that both TD infants and infants with ASD tended to select the shape match in both a naming and non-naming condition in their pointing paradigm. Despite this, in their intermodal preferential looking (IPL) task, the TD children showed a looking preference for the shape match in the name trials compared with the no name trials, although the children with ASD did not. The authors claim that their participants with ASD did not show a shape bias as it is specific to word learning. However, by this definition, the TD participants also failed to show a shape bias for the pointing task; for three out of the four testing sessions they selected the shape match for both the name and no name trials.

There are several possible reasons for the discrepancy in findings between our study and Tek et al. (2008). They only used a colour match distractor test object, while we included a texture as well as colour match, decreasing the possibility of children picking the shape match purely due to chance. We also ruled out simple preference for the test objects in the control trials, which found that participants did not choose the shape match as their favourite object above chance levels.

As Tek et al. (2008) did not include a favourite object control task, it may have been the case that (unlike the present study) children with ASD picked the shape match as they found it salient. Tek et al. (2008) consider this possibility, but stress that this explanation does not account for why the children with ASD performed at chance on the IPL task, which used the same objects as the pointing paradigm. The wording of the test question was also different in the no name condition of Tek et al. (2008) (*'point to the same'*) from our study (*'give me the other one'*), although this does not explain the differing performance between our younger group with ASD in the name condition and those in Tek et al. (2008).

Perhaps crucially, Tek et al. (2008) employed a within, rather than between, subjects design. If children completed the IPL task prior to the pointing task, by the time of the pointing task, they would have experienced repeated exposure to the objects. Past research (e.g. Smith et al. 2002; Ware and Booth 2010) suggests that the shape bias can be facilitated in TD children as young as 17 months old through repeated training. Perhaps the children with ASD's exposure to the novel object and shape match over multiple trials in Tek et al. (2008) heightened children's attention towards shape and facilitated the selection of the shape match. Consequently, the performance of the children with ASD in Tek et al. (2008) may simply reflect a learnt response over multiple trials, rather than a strong shape bias.

The participant demographics were also different in Tek et al. (2008) from our study. Firstly, Tek et al. (2008) recruited younger participants. However, it seems unlikely that toddlers with ASD select the shape match in both a name and no name context, lose this ability later on in development and then regain it a few years later, but only when the object is named. Secondly, Tek et al. (2008) admit that they obtained small effect sizes. In contrast, we found primarily medium to large effect sizes across group and chance comparisons. Therefore, we can be reasonably confident that our effects were reliable.

Of course, our study was not without its limitations. Although including the DD participants extends past research investigating the shape bias in ASD (Hartley and Allen 2014; Tek et al. 2008), the fact that our DD children had such a wide variety of conditions means that it is difficult to make inferences about how children with specific disorders would respond. Future research investigating the shape bias in atypical populations should aim to recruit groups of children with particular disorders, such as a whole cohort of children with Down syndrome or a whole cohort of children with intellectual disability in order to tease apart whether children with specific disorders show a shape bias deficit. Furthermore, a longitudinal study similar to that employed by Tek et al. (2008) would perhaps have been preferable to simply testing the children once. Longitudinal research would have allowed us to track children's behaviour over time, possibly enabling us to pinpoint the exact period at which the shape bias occurs in ASD. Given the division of the children into 'low VMA' and 'high VMA' subgroups, we can conclude that the shape bias in ASD develops at some point between the VMA of three and six, but the exact age of onset remains undetermined.

In conclusion, by studying children with ASD, who have referential intent difficulties, this research was the first to pit the SAC account directly against the ALA. Interestingly, although low VMA children with ASD do not possess the shape bias, high VMA children with ASD *do* show the heuristic, when the object is named. This study also highlights the importance of recruiting an additional control group of DD children within ASD research. Previous work has largely overlooked the shape bias in relation to DD children (although see Jones 2003). Our research suggests that DD children select the shape match at the usual developmental time point when the object is named but, unlike TD children, do not select the shape match in a non-naming context.

Critically, the SAC account and ALA *both* seem to underlie the shape bias, but for different populations. The data presented here support the SAC account for TD children and the ALA for children with ASD and DD. Future research should examine whether this is a robust finding. If so, its implications for the emergence and organisation of word learning in the three populations should be explored, in terms of both a theoretical account of the different routes to word learning and for intervention programs for language training in each of these groups.

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References

Baldwin, D. A. (1989). Priorities in children's expectations about object label reference: Form over colour. *Child Development, 60*, 1291–1306. doi:10.2307/1130921.

Baron-Cohen, S., Baldwin, D. A., & Crowson, M. (1997). Do children with autism use the speaker's direction of gaze strategy to crack the code of language? *Child Development, 68*, 48–57. doi:10.2307/1131924.

Bartolucci, G., Pierce, S. J., Streiner, D., & Eppel, P. T. (1976). Phonological investigation of verbal autistic and mentally retarded subjects. *Journal of Autism and Childhood Schizophrenia, 6*, 303–316. doi:10.1007/BF01537908.

Bloom, P. (2000). *How children learn the meaning of words*. Cambridge, MA: MIT Press.

Boucher, J. (2012). Research review: Structural language in autistic spectrum disorder—Characteristics and causes. *Journal of Child Psychology and Psychiatry, 53*, 219–233. doi:10.1111/j.1469-7610.2011.02508.x.

Charman, T., Drew, A., Baird, C., & Baird, G. (2003). Measuring early language development in preschool children with autism spectrum disorder using the MacArthur Communicative Development Inventory (infant form). *Journal of Child Language, 30*, 213–236. doi:10.1017/S0305000902005482.

D'Entremont, B., & Yazbek, A. (2007). Imitation of intentional and accidental actions by children with autism. *Journal of Autism and Developmental Disorders, 37*, 1665–1678. doi:10.1007/s10803-006-0291-y.

De Giacomo, A., & Fombonne, E. (1998). Parental recognition of developmental abnormalities in autism. *European Child and Adolescent Psychiatry, 7*, 131–136. doi:10.1007/s007870050058.

Diesendruck, G., & Bloom, P. (2003). How specific is the shape bias? *Child Development, 74*, 168–178. doi:10.1111/1467-8624.00528.

Dunn, L. M., Dunn, L. M., Whetton, C., & Burley, J. (1997). *The British picture vocabulary scale* (2nd ed.). Great Britain: National Foundation for Educational Research.

Eigsti, I. M., & Bennetto, L. (2009). Grammaticality judgments in ASD: Deviance or delay. *Journal of Child Language, 36*, 999–1021. doi:10.1017/S0305000909009362.

Eigsti, I. M., de Marchena, A. B., Schuh, J. M., & Kelley, E. (2011). Language acquisition in autism spectrum disorders: A developmental review. *Research in Autism Spectrum Disorders, 5*, 681–691. doi:10.1016/j.rasd.2010.09.001.

Eisenmajer, R., & Prior, M. (1991). Cognitive linguistic correlates of 'theory of mind' ability in autistic children. *British Journal of Developmental Psychology, 9*, 351–364. doi:10.1111/j.2044-835X.1991.tb00882.x.

Franken, T. E., Lewis, C., & Malone, S. A. (2010). Brief report: Are children with autism proficient word learners? *Journal of Autism and Developmental Disorders, 40*, 255–259. doi:10.1007/s10803-009-0847-8.

Frith, U. (1989). *Autism: Explaining the enigma*. Oxford: Blackwell.

Frith, U., Morton, J., & Leslie, A. (1991). The cognitive basis of a biological disorder: Autism. *Trends in Neurosciences, 14*, 433–438. doi:10.1016/0166-2236(91)90041-R.

Gastgeb, H., Strauss, M., & Minshew, N. (2006). Do individuals with autism process categories differently? The effect of typicality and development. *Child Development, 77*, 1717–1729. doi:10.1111/j.1467-8624.2006.00969.x.

Gastgeb, H. Z., Wilkinson, D. A., Minshew, N. J., & Strauss, M. S. (2011). Can individuals with autism abstract prototypes of natural faces? *Journal of Autism and Developmental Disorders, 41*, 1609–1618. doi:10.1007/s10803-011-1190-4.

Graham, S. A., & Diesendruck, G. (2010). Fifteen-month-old infants attend to shape over other perceptual properties in an induction task. *Cognitive Development, 25*, 111–123. doi:10.1016/j.cogdev.2009.06.002.

Happé, F. (1995). The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Development, 66*, 843–855. doi:10.1111/j.1467-8624.1995.tb00909.x.

Happé, F., & Frith, U. (2006). The weak central coherence account: Detail focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 36*, 5–25. doi:10.1007/s10803-005-0039-0.

Hartley, C., & Allen, M. L. (2014). Generalisation of word-picture relations in children with autism and typically developing children. *Journal of Autism and Developmental Disorders, 44*, 2064–2071. doi:10.1007/s10803-014-2074-1.

Howlin, P. (1984). The acquisition of grammatical morphemes in autistic children: A critique and replication of the findings of Bartolucci, Pierce, and Streiner, 1980. *Journal of Autism and Developmental Disorders, 14*, 127–136. doi:10.1007/BF02409656.

Imai, M., Gentner, D., & Uchida, N. (1994). Children's theories of word meaning: The role of shape similarity in early acquisition. *Cognitive Development, 9*, 45–75. doi:10.1016/0885-2014(94)90019-1.

Jones, S. S. (2003). Late talkers show no shape bias in a novel name extension task. *Developmental Science, 6*, 477–483. doi:10.1111/1467-7687.00304.

Karmiloff, K., & Karmiloff-Smith, A. (2001). *Pathways to language: From fetus to adolescent*. Cambridge, Mass: Harvard University Press.

Karmiloff-Smith, A., D'Souza, D., Dekker, T. M., Van Herwegen, J., Xu, F., Rodic, M., & Ansari, D. (2012). Genetic and environmental vulnerabilities in children with neurodevelopmental disorders. *PNAS, 109*, 17261–17265. doi:10.1073/pnas.1121087109.

Klinger, L. G., & Dawson, G. (2001). Prototype formation in autism. *Development and Psychopathology, 13*, 111–124. doi:10.1017/S0954579401001080.

Koldewyn, K., Jiang, Y. V., Weigelt, S., & Kanwisher, N. (2013). Global/Local Processing in Autism: Not a Disability, but a Disinclination. *Journal of Autism and Developmental Disorders, 43*, 2329–2340. doi:10.1007/s10803-013-1777-z.

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development, 3*, 299–321. doi:10.1016/0885-2014(88)90014-7.

Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (2002). *Autism diagnostic observation schedule* (WPS ed.). Los Angeles: Western Psychological Services.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview—Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*, 659–685. doi:10.1007/BF02172145.

Lovaas, O. I. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychology, 55*, 3–9. doi:10.1037/0022-006X.55.1.3.

Markman, E. M. (1989). *Categorization and naming in children*. Cambridge, MA: MIT Press.

Markson, L., Diesendruck, G., & Bloom, P. (2008). The shape of thought. *Developmental Science, 11*, 204–208. doi:10.1111/j.1467-7687.2007.00666.x.

Menyuk, P. (1978). Language: What's wrong and why? In M. Rutter & E. Schopler (Eds.), *Autism: A reappraisal of concepts and treatment* (pp. 105–116). New York: Plenum.

Mitchell, S., Brian, J., Zwaigenbaum, L., Roberts, W., Szatmari, P., Smith, I., & Bryson, S. (2006). Early language and communication development of infants later diagnosed with autism spectrum disorder. *Journal of Developmental and Behavioral Pediatrics, 27*, S69–S78. doi:10.1097/00004703-200604002-00004.

Mottron, L., Burack, J. A., Iarocci, G., Belleville, S., & Enns, J. T. (2003). Locally oriented perception with intact global processing among adolescents with high-functioning autism: Evidence from multiple paradigms. *Journal of Child Psychology and Psychiatry, 44*, 904–913.

Naigles, L. R., Kelley, E., Troyb, E., & Fein, D. (2013). Residual difficulties with categorical induction in children with a history of autism. *Journal of Autism and Developmental Disorders, 43*, 2048–2061. doi:10.1007/s10803-012-1754-y.

Nakagawa, S. (2004). A farewell to Bonferroni: The problems of low statistical power and publication bias. *Behavioral Ecology, 15*, 1044–1045. doi:10.1093/beheco/arh107.

Norbury, C. F., Griffiths, H., & Nation, K. (2010). Sound before meaning: Word learning in autistic spectrum disorders. *Neuropsychologia, 48*, 4012–4019. doi:10.1016/j.neuropsychologia.2010.10.015.

Parish-Morris, J., Hennon, E. A., Hirsh-Pasek, K., Golinkoff, R. M., & Tager-Flusberg, H. (2007). Children with autism illuminate the role of social intention in word learning. *Child Development, 78*, 1265–1287. doi:10.1111/j.1467-8624.2007.01065.x.

Perneger, T. V. (1998). What's wrong with Bonferroni adjustments? *British Medical Journal, 316*, 1236–1238. doi:10.1136/bmj.316.7139.1236.

Plaisted, K., Swettenham, J., & Rees, L. (1999). Children with autism show local precedence in a divided attention task and global precedence in a selective attention task. *Journal of Child Psychology and Psychiatry, 40*, 733–742. doi:10.1111/1469-7610.00489.

Preissler, M. A. (2008). Associative learning of pictures and words by low functioning children with autism. *Autism, 12*, 231–248. doi:10.1177/1362361307088753.

Preissler, M. A., & Carey, S. (2004). Do both pictures and words function as symbols for 18-and 24-month-old children? *Journal of Cognition and Development, 5*, 185–212. doi:10.12007/s15327647jcd0502_2.

Preissler, M. A., & Carey, S. (2005). The role of inferences about referential intent in word learning: Evidence from autism. *Cognition, 97*, B13–B23. doi:10.1016/j.cognition.2005.01.008.

Prizant, B. M., & Wetherby, A. M. (1987). Communicative intent: A framework for understanding social-communicative behavior in autism. *Journal of the American Academy of Child and Adolescent Psychiatry, 26*, 472–479. doi:10.1097/00004583-198707000-00002.

Raven, J. C. (2003). *Raven's coloured progressive matrices*. Oxford: Information Press.

Rice, M. L., Warren, S. F., & Betz, S. K. (2005). Language symptoms of developmental language disorders: An overview of autism, down syndrome, fragile X, specific language impairment and williams syndrome. *Applied Psycholinguistics, 26*, 7–27. doi:10.1017/S0142716405050034.

Rothman, K. J. (1990). No adjustments are needed for multiple comparisons. *Epidemiology, 1*, 43–46. doi:10.1097/00001648-199001000-00010.

Rutter, M., Bailey, A., Berument, S. K., Lord, C., & Pickles, A. (2003). *Social Communication Questionnaire (SCQ)*. Los Angeles, CA: Western Psychological Services.

Samuelson, L. K. (2002). Statistical regularities in vocabulary guide language acquisition in connectionist models and 15–20-month-olds. *Developmental Psychology, 38*, 1016–1037. doi:10.1037//0012-1649.38.6.1016.

Samuelson, L. K., & Smith, L. B. (2005). They call it like they see it: Spontaneous naming and attention to shape. *Developmental Science, 8*, 182–198. doi:10.1111/j.1467-7687.2005.00405.x.

Schopler, E., Reichler, R., & Rochen Renner, B. (1988). *The Childhood Autism Rating Scale (CARS)*. Los Angeles, CA: Western Psychological Services.

Smith, L. B., Jones, S. S., & Landau, B. (1996). Naming in young children: A dumb attentional mechanism? *Cognition, 60*, 143–171. doi:10.1016/0010-0277(96)00709-3.

Smith, L. B., Jones, S. S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. (2002). Object name learning provides on-the-job training for attention. *Psychological Science, 13*, 13–19. doi:10.1111/1467-9280.00403.

Tek, S., Jaffery, G., Fein, D., & Naigles, L. R. (2008). Do children with autism spectrum disorders show a shape bias in word learning? *Autism Research, 1*, 208–222. doi:10.1002/aur.38.

Van Meter, L., Fein, D., Morris, R., Waterhouse, L., & Allen, D. (1997). Delay vs. deviance in autistic social behavior. *Journal of Autism and Developmental Disorders, 27*, 557–569. doi:10.1023/A:1025830110640.

Walton, K. M., & Ingersoll, B. R. (2013). Expressive and receptive fast-mapping in children with autism spectrum disorders and typical development: The influence of orienting cues. *Research in Autism Spectrum Disorders, 7*, 687–698. doi:10.1016/j.rasd.2013.02.012.

Ware, E. A., & Booth, A. E. (2010). Form follows function: Learning about function helps children learn about shape. *Cognitive Development, 25*, 124–137. doi:10.1016/j.cogdev.2009.10.003.

Yirmiya, N., Sigman, M. D., Kasari, C., & Mundy, P. (1992). Empathy and cognition in high-functioning children with autism. *Child Development, 63*, 150–160. doi:10.1111/1467-8624.ep9203091733.